# Inductor Heater (Half Bridge) Software

# User Manual

# Revision History

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| 2010-04-06 | Kevin. Lin | V1.0.0, First draft |
| 2010-08-10 | Kevin. Lin | V1.1.0,update the main loop figure. Initialization value. |
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| | | |
| | | |

This manual contains 27 pages.

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# 1 Preface

## 1.1 About This Book

This book provides a detailed description of the half bridge inductor heater software. The user could have an overlook to the structure of the code after reading this manual. The software is developed based on MB95F430 serious MCU.

Table1.1 shows the summary of chapters included in this manual.

| Chapter Title | Description |
|---|---|
| Preface | This chapter introduces the content of this book |
| System hardware environment | This chapter introduces the MCU |
| Development environment | This chapter introduces the development tools |
| Overview of system | This chapter describes the main loop and project |
| Function description | This chapter describes the function list and prototype |
| Important details | This chapter explains some detail information |
| Additional Information | This chapter gives the website for this document |
| Appendix | This chapter gives the MCU pin usage and error code |

Table 1. 1 Chapter Summary

## 1.2 Reference Material

Use this book in conjunction with:

- Inductor Heater (Half Bridge) Demo Board User Manual v1.1.0

# 2 System Hardware Environment

- CPU Chip: Fujitsu MB95F434H;
- CPU Frequency: 8MHZ;
- Instruction Time: 0.25us;
- Ram Space: 496Bytes;
- Flash Space: 20KBytes;

# 3 Develop Environment

| Name | Description | Manufacturer | Notes |
|---|---|---|---|
| Windows XP Pro | PC OS | Microsoft | SP2 |
| Softune V3 | Software Developing IDE | Fujitsu | For FFMC-8L |
| MB95F434H Emulator | MCU Emulator | Fujitsu | --- |

# 4 Overview of System

## 4.1 Main Loop

Figure 4.1 shows the main loop of the software. When the system is powered on and the **BUTTON6** is touched, the system will run in standby mode. User can choose constant power mode or constant temperature mode by touch different button. The key and display scanning is implemented in basetimer interrupt. The period is 2ms. Key parsing and display content setting is done in main loop.

There are two time ticks in this system: four-millisecond and second, two of them are based on the 2ms interrupt.

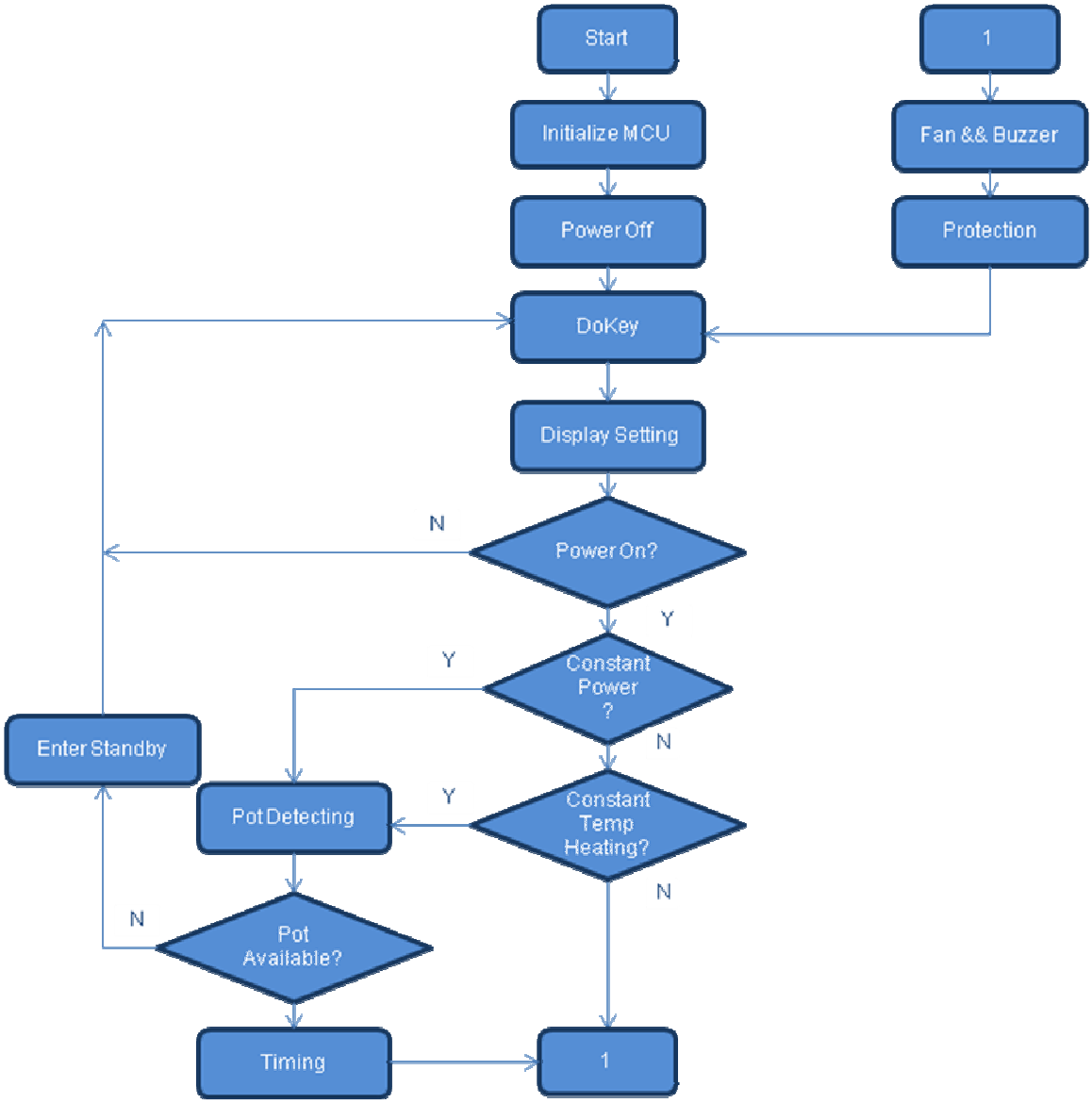
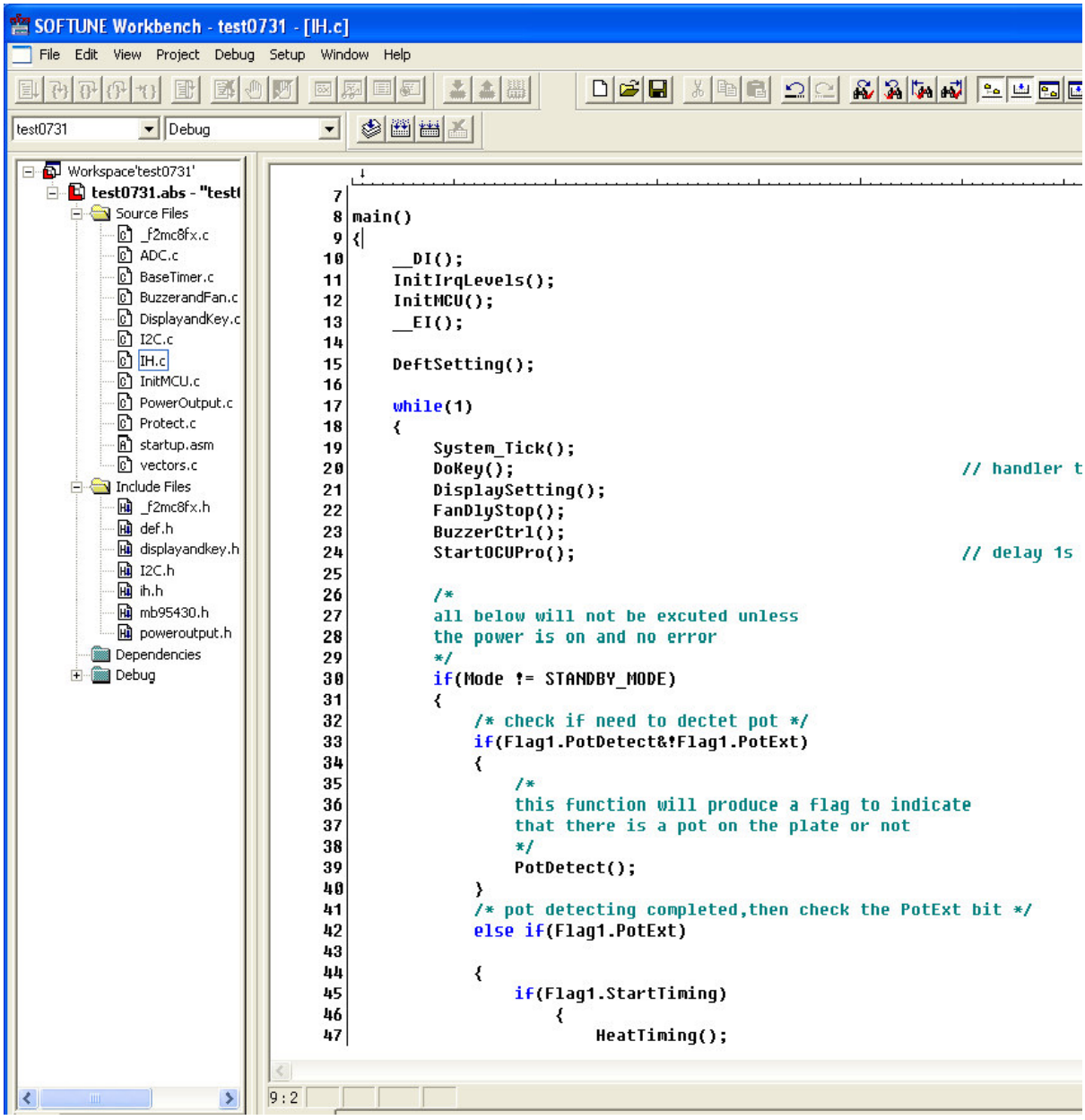



Figure 4. 1 Main Loop

## 4.2 Project

Figure 4.2 shows the project.




```
 7
 8  main()
 9  {
10      __DI();
11      InitIrqLevels();
12      InitMCU();
13      __EI();
14
15      DeftSetting();
16
17      while(1)
18      {
19          System_Tick();
20          DoKey();                                    // handler t
21          DisplaySetting();
22          FanDlyStop();
23          BuzzerCtrl();
24          StartOCUPro();                              // delay 1s
25
26          /*
27          all below will not be excuted unless
28          the power is on and no error
29          */
30          if(Mode != STANDBY_MODE)
31          {
32              /* check if need to dectet pot */
33              if(Flag1.PotDetect&!Flag1.PotExt)
34              {
35                  /*
36                  this function will produce a flag to indicate
37                  that there is a pot on the plate or not
38                  */
39                  PotDetect();
40              }
41              /* pot detecting completed,then check the PotExt bit */
42              else if(Flag1.PotExt)
43
44              {
45                  if(Flag1.StartTiming)
46                      {
47                          HeatTiming();
```

Figure 4. 2 Project

# 5 Function Description

## 5.1 Overview of the File

Table 4.1 shows the files used in this project.

| Function | Files | Description |
|---|---|---|
| Main Function | IH.c | Main application code |
| | general.h | Header file with extern definitions for main function |
| | def.h | Header file with macro definitions |
| | mb95430.h | Header file with I/O and register definitions |
| Initialization | InitMCU.c | Initialize all modules and peripherals involved |
| | def.h,mb95430.h | As described ahead |
| System Timer | BaseTimer.c | Afford time tick for system |
| | def.h | As described ahead |
| Power Management | PowerOutput.c | The file contains running mode and power adjustment functions. |
| | poweroutput.h | Header file with function and variable definitions for power management |
| | def.h,mb95430.h | As described ahead |
| Display and Key | DisplayandKey.c | The file with key parsing, display setting and scanning interrupt functions. |
| | displayandkey.h | Contains the BCD code ,function and variable definitions used in displayandkey.c |
| | def.h,mb95430.h | As described ahead |
| Protection | Protect.c | Detect the protect resource and do protect actions when illegal case occurs |
| | def.h,mb95430.h | As described ahead |
| Buzzer and Fan | BuzzerandFan.c | Buzzer and fan will be controlled in this file |
| | def.h,mb95430.h | As described ahead |
| Base Timer | basetimer.c | time ticks |
| System file | startup.asm | Start file |
| | vector.c | Configure the vector priority and address |

Table 4. 1 Related Files

## 5.2 Initialization

### 5.2.1 Function List

| Prototype | Description |
|---|---|
| void InitMCU (void) | Initialize the modules and peripherals used in this application |

### 5.2.2 Function Prototype

- void InitMCU(void)

  Input: void

  Output: void

  Description: Initialize the modules and peripherals used in this application

  Note:

  These modules or peripherals will be initialized:

  1. System clock
  2. Ports
  3. Buzzer
  4. OCU and FRT
  5. I2C module
  6. ADC
  7. Voltage comparators
  8. Base timer

## 5.3 System Timer

### 5.3.1 Function List

| Prototype | Description |
|---|---|
| void System_Tick (void) | / |
| void BaseTimer_ms (void) | Afford four- millisecond tick to system |
| void BaseTimer_s (void) | Afford second tick to system |

### 5.3.2 Function Prototype

- void System_Tick (void)

  Input: void

  Output: void

  Description: no

  Note: this function is called in main loop

- void BaseTimer_ms (void)

  Input: void

  Output: void

  Description: generate millisecond tick

  Note: this function is called in System_Tick ()

- void BaseTimer_s (void)

  Input: void

  Output: void

  Description: generate second tick

  Note: this function is called in System_Tick ()

## 5.4 Power Management

### 5.4.1 Function List

| Prototype | Description |
|---|---|
| void PotDetect (void ) | Detect the pot |
| void HeatTiming (void) | Kill the time of heat |
| void ConstantPowerMode (void) | Adjust the power level according to the setting value, and keep the power output stable |
| void ConstantTempMode (void) | Adjust the power output according to the temperature of the pot bottom, and keep it stable |
| void AdjustPower (void) | Keep the current stable |
| void StopOCUPro (void) | Stop the OCU output softly |
| void SetOCU (uchar Frequency) | Set the OCU frequency |
| uint ADC (uchar channel) | Get the voltage value on target channel |

**note** : uchar is short of unsigned char, uint is short of unsigned int

### 5.4.2 Function Prototype

- void PotDetect (void)

  Input: void

  Output: void

  Description: Detect the pot

  Note: no

- void HeatTiming (void)

  Input: void

  Output: void

  Description: Kill the time of heat

  Note: This function will shut down the system when the time is out.

- void ConstantPowerMode (void)

  Input: void

  Output: void

  Description: Adjust the power level according to the setting value, and keep the power output stable

  Note: When the PowerLevel isn't equal to PowerLevel_old, do fast adjustment, then slight adjustment.

  The range of power level is 0~8. 0---min power ,8 ---max power

- void ConstantTempMode (void)

  Input: void

  Output: void

  Description: Adjust the power output time according to temperature of the pot bottom, and keep it stable

  Note: The temperature can be set from 50 to 100 degree.

- void AdjustPower (void)

  Input: void

  Output: void

  Description: Measure the current value and keep it stable

  Note: no

- void StopOCUPro (void)

  Input: void

  Output: void

  Description: Stop the OCU output softly

  Note: To decrease the influence to power line when power off, the system has to shut down step-by-step with power level decrease.

- void SetOCU (uchar Frequency)

  Input: void

  Output: void

  Description: Set the OCU frequency

  Note: when the frequency is 0, the OCU will stop with pins cleared.

- unsigned int ADC (uchar channel)

  Input: void

  Output: void

  Description: Get the voltage value on target channel.

  Note: no

## 5.5 Display and Key

### 5.5.1 Function List

| Prototype | Description |
|---|---|
| void DoKey (void) | Parse the key value |
| void DisplaySetting (void) | Update the display content |
| void ErrorDisplay (void) | Display the error code |
| void NormalDisplay (void) | Display normal content |
| void ConfirmSetting (void) | Make a 5s delay before confirming the settings |
| uchar *DECtoBCD (uchar DecValue) | Convert decade code to BCD code |
| uchar AT5088_Read (uchar chip_id, uchar Addr) | Read given register of AT5088 through I2C module |
| void AT5088_Write (uchar chip_id, uchar Addr, uchar Data) | Write given register of AT5088 through I2C module |

### 5.5.2 Function Prototype

- void DoKey (void)

  Input: void

  Output: void

  Description: Parse the key value

  Note:

  This is the button definition and corresponding code below:

  ON/OFF -- 0x40

  TIMING -- 0x80

  INCREASE -- 0x20

  DECREASE -- 0x10

  RIGHT -- 0x08

  LEFT -- 0x04

  CONST PWR -- 0x02

  CONST TEMP -- 0x01

- void DisplaySetting (void)

  Input: void

  Output: void

  Description: Update the display content

  Note: Update the display content including error display and normal display. If the error code is 0, normal display routine will be executed; otherwise the error display routine will be executed.

- void ErrorDisplay (void)

  Input: void

  Output: void

  Description: Display the error code

  Note: This function is called in DisplaySetting ()

- void NormalDisplay (void)

  Input: void

  Output: void

  Description: Display the normal content,

  Note: This function is called in DisplaySetting ()

- void ConfirmSetting (void)

  Input: void

  Output: void

  Description: Make a 5s delay before confirming the settings

  Note: Each touch for setting will refresh the 5s counter. This function is called in DoKey ().

- uchar *DECtoBCD (uchar DecValue)

  Input: uchar DecValue

  Output: BCDCode [ ]

  Description: Convert decade code to BCD code

  Note: the max input decade value is 999.

- uchar AT5088_Read (uchar chip_id, uchar Addr)

  Input: uchar chip_id, uchar Addr

  Output: uchar Button

  Description: Enable to read the given register of AT5088 through I2C module

  Note: This function is called in TimerBase_ISR ()

- void AT5088_Write (uchar chip_id, uchar Addr)

  Input: uchar chip_id, uchar Addr

  Output: void

  Description: Enable to write the given register of AT5088 through I2C module

  Note: This function is called in TimerBase_ISR ()

## 5.6 Protection

### 5.6.1 Function List

| Prototype | Description |
|---|---|
| void Protect (void) | Get the protect resource inputs, and do protection when illegal events occur. |

### 5.6.2 Function Prototype

- void Protect (void)

  Input: void

  Output: void

  Description: Get the protect resource inputs, and do protection when illegal events occur.

  Note: This function is called in main loop

## 5.7 Others

### 5.7.1 Function List

| Prototype | Description |
|---|---|
| void FanCtrl (void) | Control the fan |
| void BuzzerCtrl (void) | Control the buzzer |

### 5.7.2 Function Prototype

- void FanCtrl (void)

  Input: void

  Output: void

  Description: Control the fan

  Note: 1. When the OCU is enabled, the fan will run.

  2. When the OCU is disabled, the fan will go on running for 1minute.

- void BuzzerCtrl (void)

  Input: void

  Output: void

  Description: Control the buzzer

  Note: Each sound will last for 200 ms.

# 6 Important Details

## 6.1 Initialization

Table 6.1shows the modules and peripherals used in this system and their initial state.

| Module or peripheral | Initial state |
|---|---|
| system clock | main osc clock = 8MHz, MCLK = 4MHz |
| output compare unit | CLK= MCLK , up-down mode, output disabled, buffer enabled , HW_STOP enabled |
| free-run timer | clock = ¼ MCLK, up-down mode, |
| I2C bus | clock = MCLK, Fsck = 83K, interrupt mode |
| ADC | clock = ¼ MCLK, 10bit data format, start by AD bit |
| base timer | 2ms |
| port | according to the function of the port |

Table 6. 1 Initial State

The system is initialized to power off state with all display off.

## 6.2 Power Adjustment

The Induction Cooking board works on the principle of a series L-C resonant circuit. When the size of L and C are set, the resonant frequency is set as well. Unfortunately, this value does not depend only on the resonant tank. In fact, the size and material of the pot affect the resonant frequency too. This causes the system to have an oscillatory resonant frequency strongly depending on the type of pot placed on the plate. So each power level does not work on a constant PWM frequency, but a constant current.

In this system, the power adjustment includes two steps: fast adjustment and slight adjustment. The fast adjustment is done per second before the real power level equals to the target power level. The slight adjustment will be done after the fast adjustment is completed.

## 6.3 Pot Detection

Actually, the inductor heater won't heat if there is no pot on the heat plate, that is protection act in fact. Before heating. the system will output a period of pulse sequence and measuring the AC current. If there is a pot on the heat plate, the current will be much higher than that there is no pot on the heat plate.

Figure 6.1 shows the flow of pot detection.

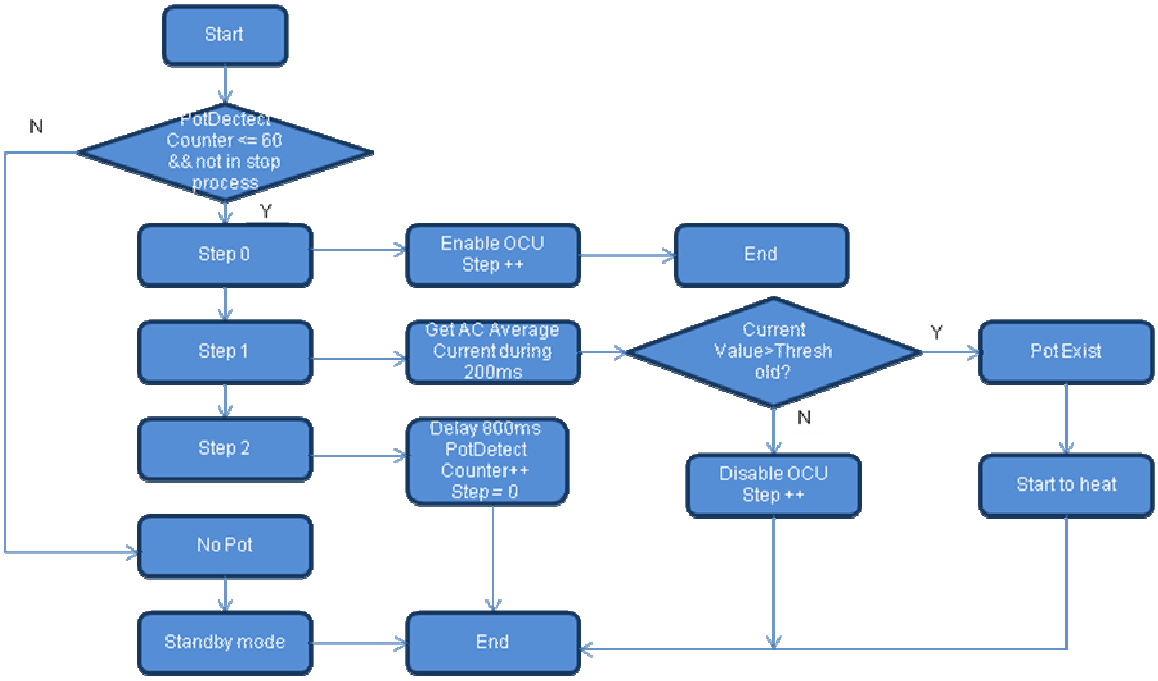



Figure 6. 1 Pot Detection

## 6.4 Mode Switch

This inductor heater has three modes: constant power, constant temperature and timing. The two modes ahead are mutually exclusive. The timing mode can coexist with one of others.

In constant power mode, the system will keep the power output stable.

In constant temperature mode, the system will keep the temperature of the pot bottom stable.

If timing mode is selected, the system will run in constant power mode or constant temperature mode until the time is out, then the system will enter standby automatically.

## 6.5 Protection

There are five kinds of protection for this system: over current, surge, over voltage, IGBT over temperature, pot over temperature and pot removed protection.

Over current is implemented by comparator 1. it will monitor the resonant current flowing the resonant tank. When over current occurs, the system will break for 30 s.

Surge is implemented by comparator 2. it will monitor the rectifier module output voltage. When Surge occurs, the system will break for 30 s.

Over voltage protection will protect the system from high voltage (256VAC) or low voltage (187VAC) input. If that happens, the system will stop and alarm. ADC channel 0 is used to monitor the AC voltage.

IGBT over temperature is implemented ADC channel AN07. When the temperature of IGBT is higher than 80 centigrade degree, the system will stop until the temperature return to normal area.

If the temperature of pot bottom exceeds 200 centigrade degree. The pot over temperature protection will take effect. the system will stop until the temperature return to normal area.

If the pot is removed during heating, the OCU also will stop to protect the IGBT stage.

The error code can be found in chapter 8 *Appendix.*

## 6.6 Key and display

The key and display function is mainly implemented using AT5088 that is a capacity touch chip. It exchange the key and display data with MCU by hardware I2C bus. The MCU will communicate with AT5088 once per 2ms. The user can found the code in the file *DisplayandKey.c .*

## 6.7 Important variable and flag

Figure 6.2 shows the important variable and flag as below:

| Variable or flag | Description |
|---|---|
| Mode | 0--standby mode mode,1--constant power mode, 2--constant temperature mode |
| PowerLevel_new | power level that user can select. level 0~level 8 |
| PowerLevel_new_buf | power level buffer for flicker display when setting. level 0~level 8 |
| PowerLevel_old | the previous power level. level 0~level 8 |
| PotTemp | Pot temperature that user can set. 50 ~100 degree |
| PotTempbuf | Pot temperature buffer for flicker display when setting |
| PotTempExt | the actual temperature of pot |
| Hour | the hour value that user can set. 0~1 |
| Minute | the Minute value that user can set. 1~59 |
| DisplayVaule[4] | the array contains display content |
| BCDCode[10] | BCD code for display |
| CrntArray[6] | Current value to corresponding to power level |
| PulseFreq[8] | base frequency of each power level |
| Flag1.ONorOFF | 1--ON,0--OFF |
| Flag1. PotDetect | 1--detect pot, 0-- don't detect pot |
| Flag1.PotExt | 1--pot exists, 0-- no pot |

Table 6. 2 Important Variable and Flag

# 7 Additional Information

For more information on FUJITSU MICROELECTRONICS products, please visit the following website at:
Simplified Chinese Version: http://www.fujitsu.com/cn/fmc/services/mcu/mb95430/
English Version: http://www.fujitsu.com/cn/fmc/en/services/mcu/mb95430/

# 8 Appendix

## 8.1 List of Figure

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## 8.2 List of Table

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Table 6. 2 Important Variable and Flag ..... 23

## 8.3 MCU Usage

| Pin Number | Pin Name | Function |
|---|---|---|
| 1 | PG2/PPG0/X1A/OUT1 | Sub clock |
| 2 | PG1/TRG0/ADTG/X0A | Sub clock |
| 3 | Vcc | Vcc |
| 4 | C | C |
| 5 | P60/OPAM_P | Fan |
| 6 | P61/OPAM_N | LED COM0 |
| 7 | P62/OPAM_O | SYS_PW |
| 8 | P12/EC0/UI/DBG | DBG |
| 9 | P00/INT00/AN00 | System voltage measuring |
| 10 | P01/INT01/AN01/BZ | Buzzer |
| 11 | P02/INT02/AN02/UCK | NULL |
| 12 | P03/INT03/AN03/UO | SDA for I2C |
| 13 | P04/INT04/AN04/UI | SCL for I2C |
| 14 | P05/INT05/AN05/TO0 | System current measuring |
| 15 | P06/INT06/AN06/TO1 | Plate temperature measuring |
| 16 | P07/INT07/AN07/EC0 | IGBT temperature measuring |
| 17 | P70/CMP0_O/OUT0 | IGBT driver H |
| 18 | P71/CMP0_P | LED COM2 |
| 19 | P72/CMP0_N | LED COM3 |
| 20 | P73/CMP1_O/OUT1 | IGBT driver L |
| 21 | P74/CMP1_P | OC protection reference voltage |
| 22 | P75/CMP1_N | OC input |
| 23 | P76/CMP2_O/UCK | LED COM1 |
| 24 | P63/CMP2_P | Surge protection reference voltage |
| 25 | P64/CMP2_N | Surge input |
| 26 | P65/CMP3_O/UO | LED COM4 |
| 27 | P66/CMP3_P | Short circuit protect reference voltage |
| 28 | P67/CMP3_N | Short circuit protect |
| 29 | PF2/RSTX | Reset |
| 30 | PF0/X0 | oscillator |
| 31 | PF1/X1 | oscillator |
| 32 | Vss | Vss |

## 8.4 ErrorCode

| Error Code | Description | Notes |
|---|---|---|
| E0 | HW_STOP is set | |
| E1 | Low voltage | the power supply is lower than 185V |
| E2 | Over voltage | the power supply is higher than 256V |
| E3 | Pot temperature sensor is short | |
| E4 | Pot temperature sensor is open | |
| E5 | IGBT temperature sensor is short | |
| E6 | IGBT temperature sensor is open | |
| E7 | Pan over temperature | the temperature of pan bottom is higher than 200 °C |
| E8 | IGBT over temperature | the temperature of IGBT is higher than 80 °C |